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INFORMAL REPORT

OCEANOGRAPHIC CRUISE SUMMARY
ROSS SEA, ANTARCTICA

DECEMBER 1967

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ABSTRACT

Oceanographic survey was performed in the Ross Sea, Antarctica, from 25 January to 8 March 1967 aboard GLACIER and STATEN ISLAND. Oceanographic stations were occupied in the central part of the sea to complement previous work done by NAVOCEANO in the investigation of Circumpolar Water intrusion into the Ross Sea and at the annual ice forecasting station locations. Current meter arrays were moored at two locations for direct current readings, and a special bathymetric survey was conducted along the Victoria Land coast.

Preliminary analysis of oceanographic station data indicates that the main intrusion of Circumpolar Water enters the Ross Sea at about 174°W longitude and that bottom topography is an influencing factor in deflecting this water southward into the Ross Sea.

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Nearshore Surveys Division
Oceanographic Surveys Department

This report has been reviewed and is approved for release as an UNCLASSIFIED Informal Report.

L B Berthold

L. B. BERTHOLF
Director, Nearshore Surveys Division

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I. PREVIOUS KNOWLEDGE OF THE REGION

The Antarctic Continent is encircled by the broad, eastward flowing Circumpolar Current. The prevailing wind direction in this area is westerly with an associated net horizontal transport of surface water to the north. According to the law of continuity, this northerly transport of surface water must be compensated by a southerly transport at a deeper depth. Thus, according to Midttum and Natvig (1957), the general circulation around the Antarctic Continent is that of a meridional circulation superimposed upon a general flow to the east. Evidence of this southward transport is the presence of a warm layer between the surface and bottom water layers found around the Continent.

The intrusion of this warm, subsurface layer into the Ross Sea can easily be detected by its higher temperature and salinity and is known as Antarctic Circumpolar Water. Two other well defined water masses, Upper Water and Shelf Water, are present in the Ross Sea. Upper Water is subdivided into Antarctic Surface Water and Winter Water. The deeper layer of the Upper Water has been called Winter Water by Mosby (1934) because this layer has the same characteristics that the Upper Water had during the previous winter. Surface Water, according to Deacon (1937), is a surface layer which has a higher temperature and lower salinity than Winter Water due to summer heating and ice melt. Shelf Water is the most dense water mass in the Ross Sea and is characterized by cold temperatures and high salinities.

Countryman and Gsell (1966), from their investigation of 1963 and 1964 DEEP FREEZE data, believe that the main intrusion of Circumpolar Water into the Ross Sea is north of 75°30'S between 176°W and 180°. Additional, but smaller, inflows of Circumpolar Water enter through the western and eastern Ross Sea.

II. OBJECTIVES OF THE SURVEY

The objectives of this survey were to: (1) define the movement of the Antarctic Surface, Shelf, and Circumpolar Water masses by measuring direction and speed of currents in the southern and eastern Ross Sea; (2) fill in oceanographic station holiday areas in order to complete the analysis of Circumpolar Water intrusion into the Ross Sea and complement previous work done by NAVOCEANO; (3) reduce bathymetric holiday areas along the continental shelf; and (4) occupy the annual ice forecasting oceanographic stations along the main shipping route to McMurdo and Hallett Stations.

III. NARRATIVE OF THE SURVEY

Three NAVOCEANO oceanographers and one bathymetrist joined USCGC GLACIER (WAGB 4) at McMurdo Station, Antarctica, on 25 January 1967.

After completing a bathymetric survey near Victoria Land, as requested by the National Science Foundation (NSF), two subsurface current meter arrays were moored and oceanographic stations were occupied in the central Ross Sea.

On 19 February, two oceanographers and the bathymetrist transferred from GLACIER to USCGC STATEN ISLAND (WAGB 278) to finish the remaining oceanographic stations and to begin the bottom sediment phase of the survey. The oceanographer remaining aboard GLACIER recovered the two current meter arrays.

GLACIER and STATEN ISLAND rendezvoused at Edisto Inlet off Cape Hallett on 25 February to transfer the oceanographer on GLACIER to STATEN ISLAND. GLACIER then departed the survey area leaving STATEN ISLAND to occupy the annual ice forecasting stations. STATEN ISLAND finished these stations on 1 March and arrived at Port Lyttelton, New Zealand, on 8 March.

IV. RESULTS

Personnel aboard GLACIER and STATEN ISLAND conducted observations at locations shown in Figure 1. Using GLACIER, 2 subsurface buoy arrays, each with 3 current meters, were moored, and 32 oceanographic Nansen stations were occupied. Oceanographic casts were not made below 1,400 meters due to faulty wire on the oceanographic winch. A total of 2,775 nautical miles of echo soundings was obtained along the ship's track while occupying oceanographic stations and near Victoria Land coast as requested by NSF.

STATEN ISLAND occupied 2 oceanographic Nansen stations in the central Ross Sea and the 28 annual ice forecasting stations. Fourteen bottom sediment samples were collected, and 1,935 nautical miles of echo soundings were run.

Aboard both ships, a total of 563 nutrient samples was drawn and quick frozen to be analyzed at NAVOCEANO for inorganic phosphate, nitrate, and silicate.

A station summary is presented as Table I.

V. METHODS OF COLLECTION AND ANALYSIS

A. Physical Oceanography.

1. Temperature. Paired deep sea reversing thermometers (-2° to 20°C) were utilized to record in situ water temperatures. These thermometers are considered accurate to ±0.02°C. Thermometer readings were corrected by standard procedures. The accepted temperature value was

FIGURE 1. OBSERVATION LOCATIONS

TABLE I. OCEANOGRAPHIC STATION SUMMARY

Consec. Sta. Number	Latitude °S	Longitude	Sonic Depth (m)	Cast Depth (m)	BT	Nutrients
1	77°09.3'	166°43.3'E	201	150	√	
2	72°35'	173°10'E	530	519	√	
3	70°56'	179°17.5'E	2195	1223	√	√
4	70°53.5'	177°25'W	2834	1373	√	√
5	71°25'	176°30'W	2926	1387	√	√
6	71°52.5'	174°45'W	3292	1368	√	√
7	72°53'	174°29'W	3155	1370	√	√
8	72°23'	176°00'W	914	312	√	√
9	71°57'	177°43.5'W	1006	818	√	√
10	71°24'	179°13'W	1006	836	√	√
11	75°23'	176°50'E	412	385	√	√
12	75°26'	180°	558	424	√	√
13	76°02'	178°37'W	604	567	√	√
14	75°30'	175°01.5'W	567	592	√	√
15	76°10'	172°03.5'W	448	445	√	√
16	75°52'	171°47'W	458	446	√	√
17	75°23'	172°04'W	1463	1217	√	√
18	74°52'	172°05'W	1829	1126	√	√
19	74°55'	174°04'W	1555	1212	√	√
20	74°23'	176°00'W	905	831	√	√
21	73°54.5'	174°10'W	2469	1300	√	√
22	73°26'	176°02'W	1326	1245	√	√
23	72°57.5'	177°43'W	603	588	√	√
24	72°26'	179°23'W	814	749	√	√
25	71°55'	179°05'E	2486	1107	√	√
26	72°53.7'	178°46'E	1738	1266	√	√
27	73°25.5'	179°35'W	440	418	√	√
28	73°56.5'	177°56'W	805	788	√	√
29	74°56.3'	178°06'W	412	430	√	√
30	74°12'	178°31'E	219	210	√	√
31	73°55'	177°52'E	247	222	√	√
32	74°39'	177°25.5'E	311	285		√
33	75°54.7'	177°27'E	494	444	√	√
34	74°21'	179°29'E	320	263		√

All stations taken from USCGC GLACIER except numbers 33 and 34 taken from USCGC STATEN ISLAND.

TABLE I (Cont.)

Consec. Sta. Number	Latitude °S	Longitude °E	Sonic Depth (m)	Cast Depth (m)	BT	Nutrients
35	71°54'	176°00'	1920	1404	√	
36	71°41'	175°38'	2341	225	√	
37	72°24'	170°46'	289	272	√	
38	72°16.5'	170°44'	450	332	√	
39	72°18.2'	170°10'	393	182	√	
40	72°13.5'	170°12'	777	424	√	
41	72°10'	170°41'	380	332	√	
42	72°06.5'	171°06'	384	337	√	
43	71°47'	171°57'	777	483	√	
44	71°47.5'	173°45'	2190	487	√	
45	72°30'	171°15'	360	332	√	
46	77°45'	164°55'	251	222		
47	77°44'	165°19'	403	374	√	
48	77°40'	165°46'	640	500		
49	77°36'	165°59'	576	470	√	
50	77°25.5'	166°04.5'	960	400	√	
51	76°32'	170°26'	822	400	√	
52	76°20'	168°15.0'	732	397	√	
53	76°05'	166°18'	622	400	√	
54	75°54.5'	164°58'	915	400	√	
55	74°47'	167° 26'	695	378	√	
56	74°56.8'	169°14'	364	328	√	
57	75°16'	171°02'	631	387	√	
58	75°25.5'	172°54'	548	395	√	
59	73°37.3'	176°39'	640	395	√	
60	73°39.5'	175°07.5'	505	398	√	
61	73°38.5'	173°22'	329	297	√	
62	73°33.7'	171°18'	610	400	√	

All the above are ice forecast stations and were taken from USCGC STATEN ISLAND

TABLE I (Cont.)

Bottom Sed. Number	Latitude °S	Longitude	Type Sample
1	75°54'	177°30'E	Surf. Sample
2	75°57'	178°16'W	Kullenberg
3	75°24.5'	176°02'W	Kullenberg
4	75°53.7'	173°54'W	Surf. Sample
5	75°53'	171°50'W	Kullenberg
6	75°23'	172°11'W	Kullenberg
7	74°54.5'	174°08'W	Kullenberg
8	74°25'	176°00'W	Kullenberg
9	74°57'	178°06'W	Kullenberg
10	75°27'	180°	Kullenberg
11	74°57'	178°06'E	Surf. Sample
12	74°22.5	179°33'W	Kullenberg
13	73°27'	176°16'W	Kullenberg
14	73°02'	178°12'W	Kullenberg
15	72°34'	179°55'W	Kullenberg

obtained by averaging the two readings if the values differed by 0.06°C or less. When paired thermometers differed by more than 0.06°C, the reading from the thermometer considered most reliable, based on its previous record, was used.

Three -2° to 10°C and one -2° to 20°C YOSHINO protected reversing thermometers were field tested as part of a field reliance test. Results from these thermometers were not used in determining accepted temperature values.

2. Sample Depths. Unprotected reversing thermometers paired with the protected thermometers were used to determine thermometric depth values. Depth of the sample then was computed using these thermometric depths in conjunction with observed wire angles. Attempts were made to place the Nansen bottles at standard depths.

3. Bathythermographs. A 900-foot mechanical bathythermograph (BT) lowering was made prior to most Nansen casts. In areas where ice coverage was 9/10 or greater, BT's were not attempted.

4. Current Observations. Two current meter arrays were moored in the survey area. Each array consisted of the following:

(a) a surface float equipped with a radar reflector
(b) a 500-lb. net buoyancy Danko subsurface float to support the array
(c) 3/4 inch, 2 in 1, Samson braided nylon rope mooring line
(d) three Geodyne self-recording current meters spaced along the mooring line
(e) a Geodyne timed release mechanism
(f) three 450-lb. anchors

All current meters were set to sample for 50 seconds at 10-minute intervals.

Array No. 1 was moored in 840 feet of water at 77°09.3'S and 166°43.3'E. The current meters were spaced at depths of 168 feet, 498 feet, and 810 feet below the sea surface. The total sampling time for this array was 23 days and 8 hours. The bottom current meter did not record due to a faulty film advance.

Array No. 2 was moored in 1,740 feet of water at 73°40'S and 173°10'E. The current meters were spaced at depths of 223 feet, 968 feet, and 1,709 feet below the sea surface. The total sampling time for this array was 19 days. Only directions were recorded with the bottom meter due to a broken savonius rotor.

The output from these Geodyne self-recording current meters is recorded on 16 mm photographic film which must be developed and machine read.

B. Chemical Oceanography.

1. Salinity. Water samples were collected with Nansen bottles at all sampling depths. Salinities were determined by means of an Industrial Instrument inductively coupled salinometer (Model RS-7B, Serial 22490). This instrument was field tested for accuracy by analyzing a substandard of known salinity against standard Copenhagen water. Based on this field test, salinities may be considered accurate to ±.01‰.

2. Nutrients. Samples for nutrient analyses were collected in 6-oz. polyethylene bottles and quick frozen. These samples will be analyzed for silicate, nitrate, and phosphate content at NAVOCEANO with a Beckman model DU Spectrophotometer.

The phosphate samples will be analyzed by the method described by Murphy and Riley (1962) and the silicate and nitrate samples will be analyzed according to the method described by Strickland and Parsons (1965).

C. Geological Oceanography.

1. Bottom Samples. A 6-foot Kullenberg gravity corer was used to collect all bottom samples. In cases where only a small amount of sediment was obtained, the sample was stored in a glass jar and logged as a surface sample.

2. Bathymetry. The ships' UQN/1-B was used to obtain all echo sounding tracks.

VI. DISPOSITION OF DATA

Observed Nansen cast data were coded and forwarded to the National Oceanographic Data Center (NODC) and are on file under cruise reference number 31880. Computer computations have been completed for sound velocity, sigma-t, and specific volume and dynamic height anomalies.

BT data were forwarded to NODC for processing and retention.

Current meter data, when processed, will be retained on file in Code 9210 at NAVOCEANO.

Nutrient samples are being processed at NAVOCEANO and will be available as laboratory item number 4.

Bottom sediment samples have been analyzed for engineering properties and sediment size and composition. The analyses are on file at NAVOCEANO under laboratory report number 312. Bottom sediment sample field description (log sheet M) is presented as Table II.

TABLE II. BOTTOM SEDIMENT SAMPLE FIELD DESCRIPTION

OCEANOGRAPHIC LOG SHEET - B
BOTTOM SEDIMENT DATA
NAV-OCEANO-3167/12 (Rev. [illegible])

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VESSEL: STATEN ISLAND | CRUISE: DF-67 | CHECKED BY: | DATE CHECKED:

BOTTOM SEDIMENT NO.	DATE (1967)	LATITUDE	LONGITUDE	DEPTH (Fathoms)	DEPTH (Meters)	GEOMORPHOLOGY OF IMMEDIATE AREA	TYPE OF SAMPLER	WEIGHT OF SAMPLER	APPROX. PENETRATION	LENGTH OF CORE	ROCK COLOR CHART CORE NUMBERS: CORE TOP	CORE BOTTOM	FIELD DESCRIPTION OF CORE AND REMARKS	INIT.
1	20 Feb	75°54'	177°30'E	275	503	ROSS SEA	KULLENBERG	300#	3½'	3½'			Core liner split, only top of sample retained	JPJ
2	20 Feb	75°57'	178°16'W	360	658	"	"	"	4'4"	4'1"				JWB
3	20 Feb	75°24.5	176°02'W	283	518	"	"	"	3'5"	1'				JWB
4	20 Feb	75°53.7	173°54'W	295	540	"	"	"	6"	-			Core cutter sample only	JPJ
5	20 Feb	75°53'	171°50'W	610	1116	"	"	"	5'6"	4'5"				JPJ
6	21 Feb	75°23'	172°11'W	995	1820	"	"	"	5'8"	5'2"				JWB
7	21 Feb	74°54.5	174°08'W	1200	2195	"	"	"	5'2"	4'8"				JPJ
8	21 Feb	74°25'	176°00'W	600	1097	"	"	"	5'0"	4'4"				JPJ
9	21 Feb	74°57'	178°06'W	320	585	"	"	"	-	8"				JPJ
10	22 Feb	75°27'	180°	305	558	"	"	"	4'6"	1'9"				JWB
11	22 Feb	74°57'	178°06'E	200	366	"	"	"	-	8"			Coarse material [illegible] water to drain sample. Core retained as surface sample.	JWB
12	22 Feb	74°22.5	177°33'W	175	320	"	"	"	-	2'6"			Coarse sand.	JWB
13	22 Feb	73°27'	176°16'W	650	1189	"	"	"	5'8"	3'3"				JWB
14	22 Feb	73°02'	178°12'W	305	558	"	"	"	2'	10"				JPJ
15	23 Feb	72°34'	179°55'W	1150	2103	"	"	"	3'	2'5"				JWB

Copies of the sonic soundings obtained along the Victoria Land coast were given to the NSF for retention. Original data of all sonic soundings are on file in Code 8500 at NAVOCEANO.

VII. PRELIMINARY ANALYSIS

Deacon (1963), in his discussion of the Southern Ocean, states that the general flow around the Antarctic Continent is eastward. He points out, however, based on the slope of the isotherms, that there is a westerly flow of the Deep Water in the eastern approach to the Ross Sea.

In order to show the intrusion of Antarctic Circumpolar Water into the Ross Sea, a north-south section is presented in Figure 2. This section was chosen to include only the stations with high subsurface temperature maximums. It shows the Antarctic Surface Water to be in the upper 100 meters of the water column, with no apparent difference in thickness. The Antarctic Surface Water blends directly into the warmer Circumpolar Water with no evidence of a cold Winter Water layer. Circumpolar Water, in relatively pure form, exists as far south as station 17. Stations 16 and 15 show only limited influence with the subsurface temperature maximum colder than 0°C. Since the deepest Nansen casts taken in this series of stations only went down to 1,368 m, the presence of Shelf Water is not shown.

Also, it is apparent in Figure 2 that the rapid change in depth from 1,463 m to 458 m between stations 17 and 16 acts as an effective barrier to any extensive southerly movement of Circumpolar Water; however, the effect of this warm intrusion is felt throughout the Ross Sea.

Subsurface temperature maximums and the depths at which they were found are presented in Table III.

TABLE III. SUBSURFACE TEMPERATURE MAXIMA

Station No.	Max. Temp. °C	Depth (m)
6	+ 1.44	391
7	+ 1.49	300
21	+ 1.44	250
19	+ 1.11	466-558
17	+ 1.16	416

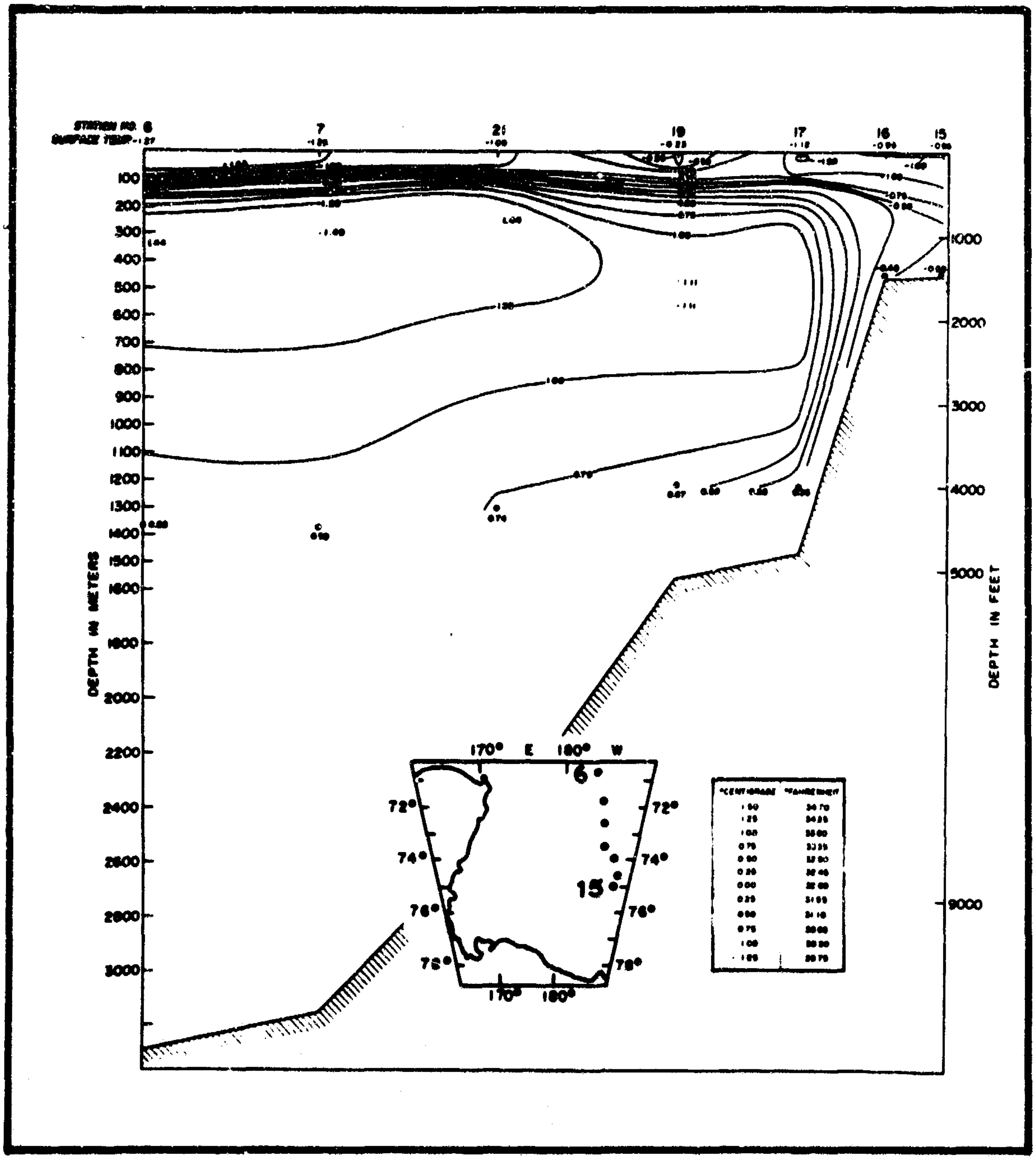

FIGURE 2. NORTH-SOUTH TEMPERATURE CROSS SECTION

From Figure 3, it appears that the main intrusion of Circumpolar Water enters the Ross Sea at about 174°W longitude. The 1,000 m bottom contour was superimposed on the 1°C isotherm, and it is apparent that the 1°C isotherm does follow the 1,000 m contour, suggesting that bottom topography may be an influencing factor in deflecting the warm Circumpolar Water southward into the Ross Sea. Upon reaching its most southerly extent, the flow is then deflected eastward.

VIII. ADDITIONAL WORK NEEDED IN THE REGION

Our knowledge of the circulation in the Ross Sea is basically derived from dynamic calculations and by tracking properties such as temperature, salinity, and oxygen. More direct current measurements, such as performed on this survey, are needed to determine how well the circulation as derived by indirect methods compares with the actual flow.

Annual ice forecasting stations are required to continue the long range ice forecasting program along the main shipping route to McMurdo Sound.

FIGURE 3. CIRCUMPOLAR WATER INTRUSION AS SHOWN BY SUBSURFACE TEMPERATURE MAXIMA

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13. ABSTRACT

Oceanographic survey was performed in the Ross Sea, Antarctica, from 25 January to 8 March 1967 aboard GLACIER and STATEN ISLAND. Oceanographic stations were occupied in the central part of the sea to complement previous work done by NAVOCEANO in the investigation of Circumpolar Water intrusion into the Ross Sea and at the annual ice forecasting station locations. Current meter arrays were moored at two locations for direct current readings, and a special bathymetric survey was conducted along the Victoria Land coast.

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